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(54) Proportional pressure-regulating valve

(57) A proportional pressure-regulating valve for an actuator (16) has a main valve (11) having a valve spool (20) which is axially displaceable from a neutral mid-position, blocking a valve port (21) connected to the actuator (16), to either side into a further position in which the valve port (21) is connected to a supply port (22) or an exhaust port (23). When the valve spool (20) is uncontrolled, it is moved by a return spring (33) into a fourth, end position in which the port (21) is isolated from both valve ports (22, 23). The valve spool (20) is rigidly connected to a damping piston (36), which de-limits a damping chamber (35). The damping chamber (35) is connected to a pilot valve (12) providing the valve spool (20) with control pressure medium. Under normal operating conditions, a minimum pressure in the damping chamber (35) prevents the damping piston (36) from entering the chamber and so deters movement of the valve spool (20) to its fourth, end position.

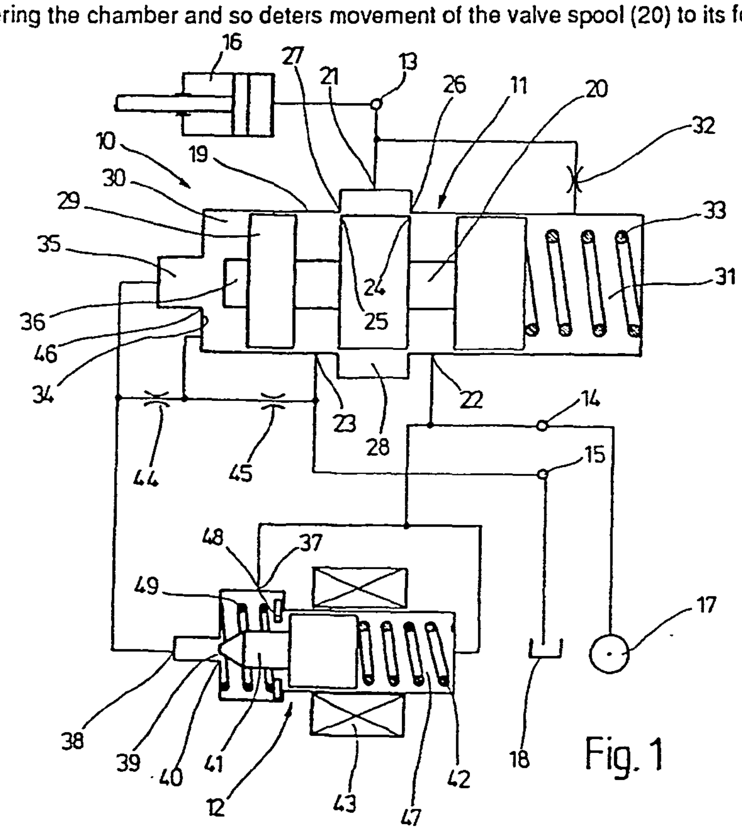

Fig. 1

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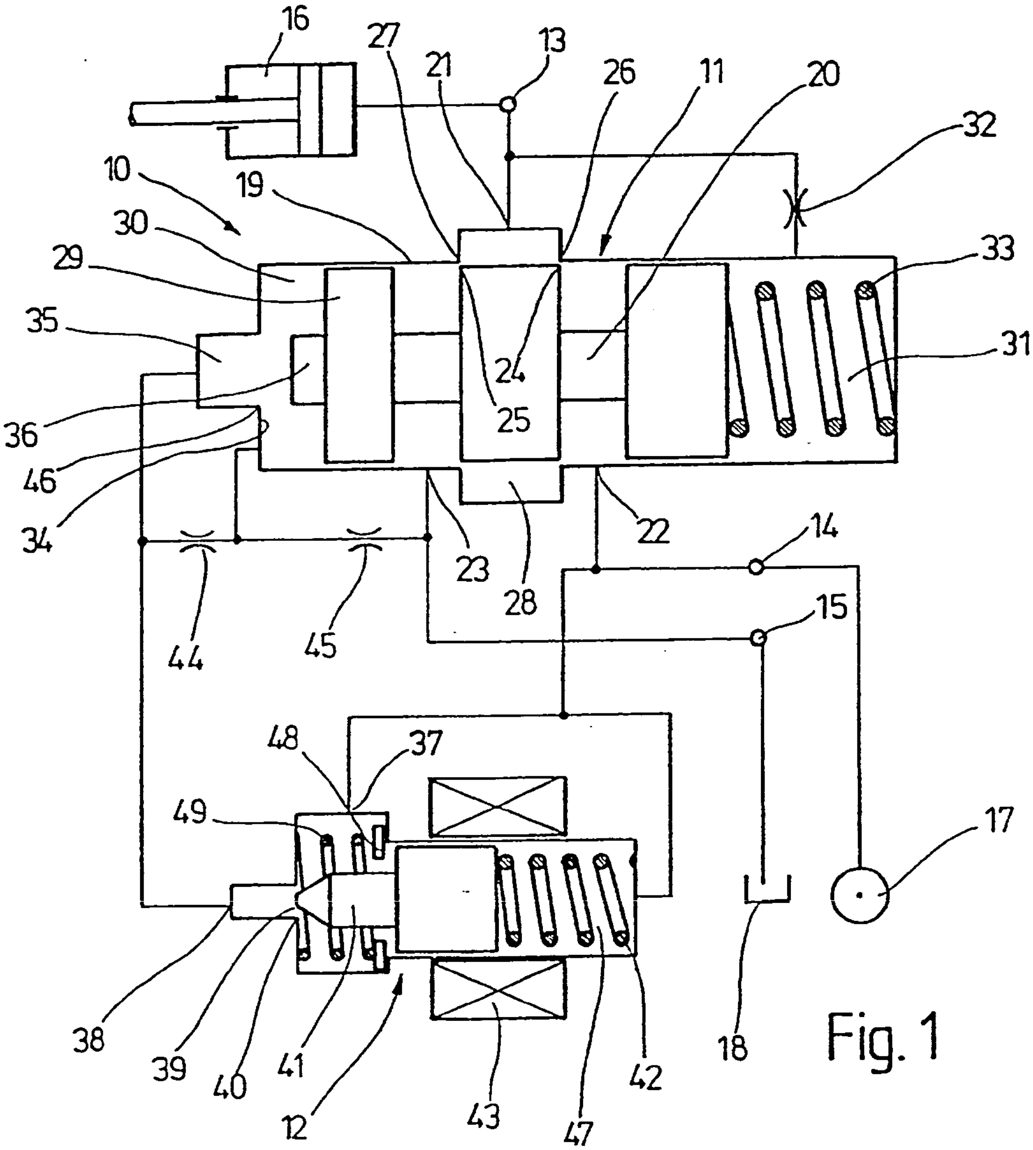

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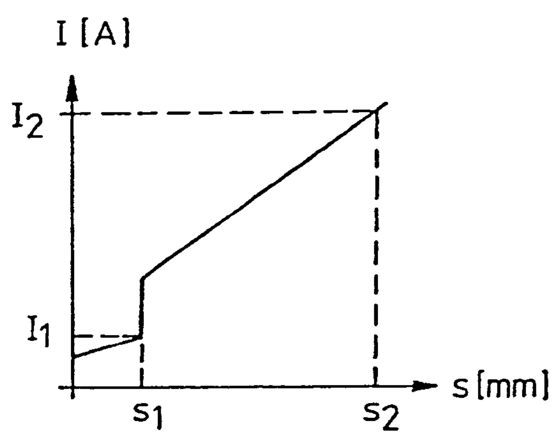
Fig. 1



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s [mm]
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s_2

Fig. 2

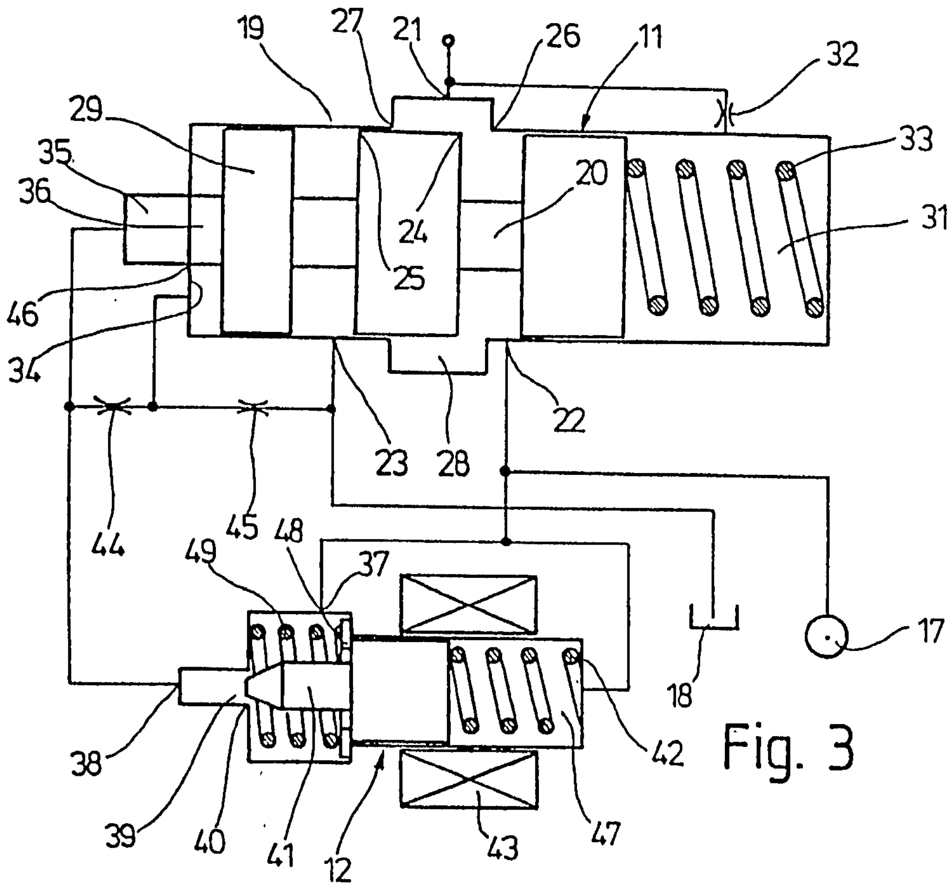
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Fig. 3

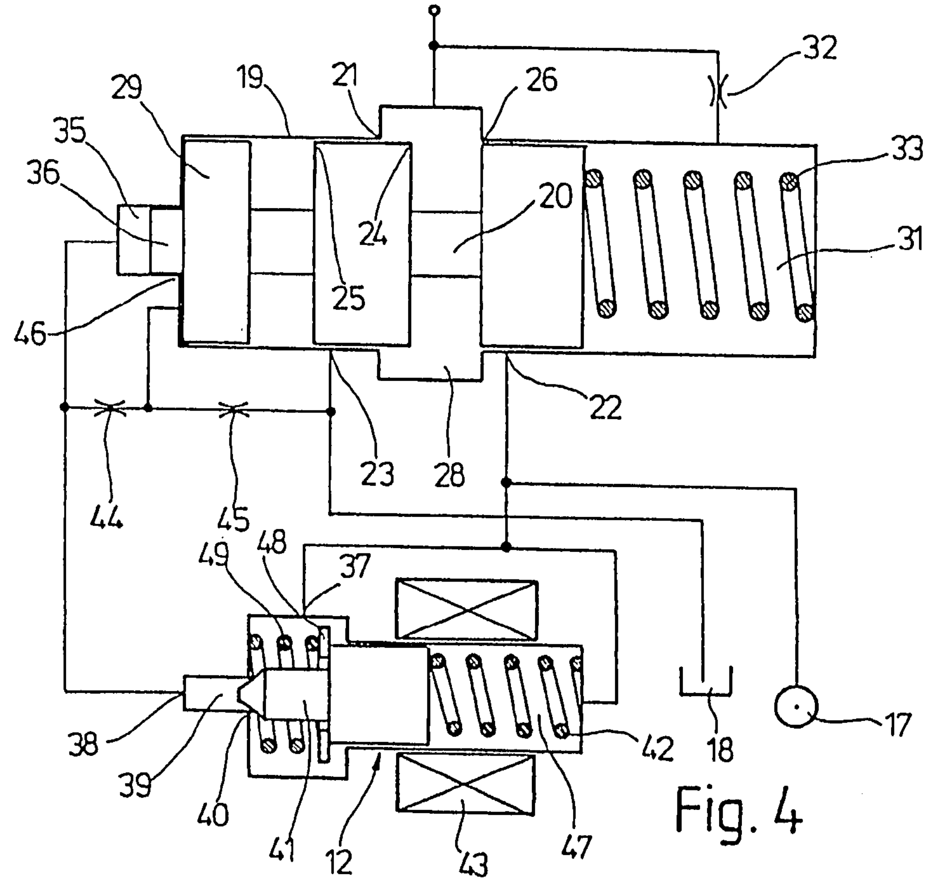
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Fig. 4

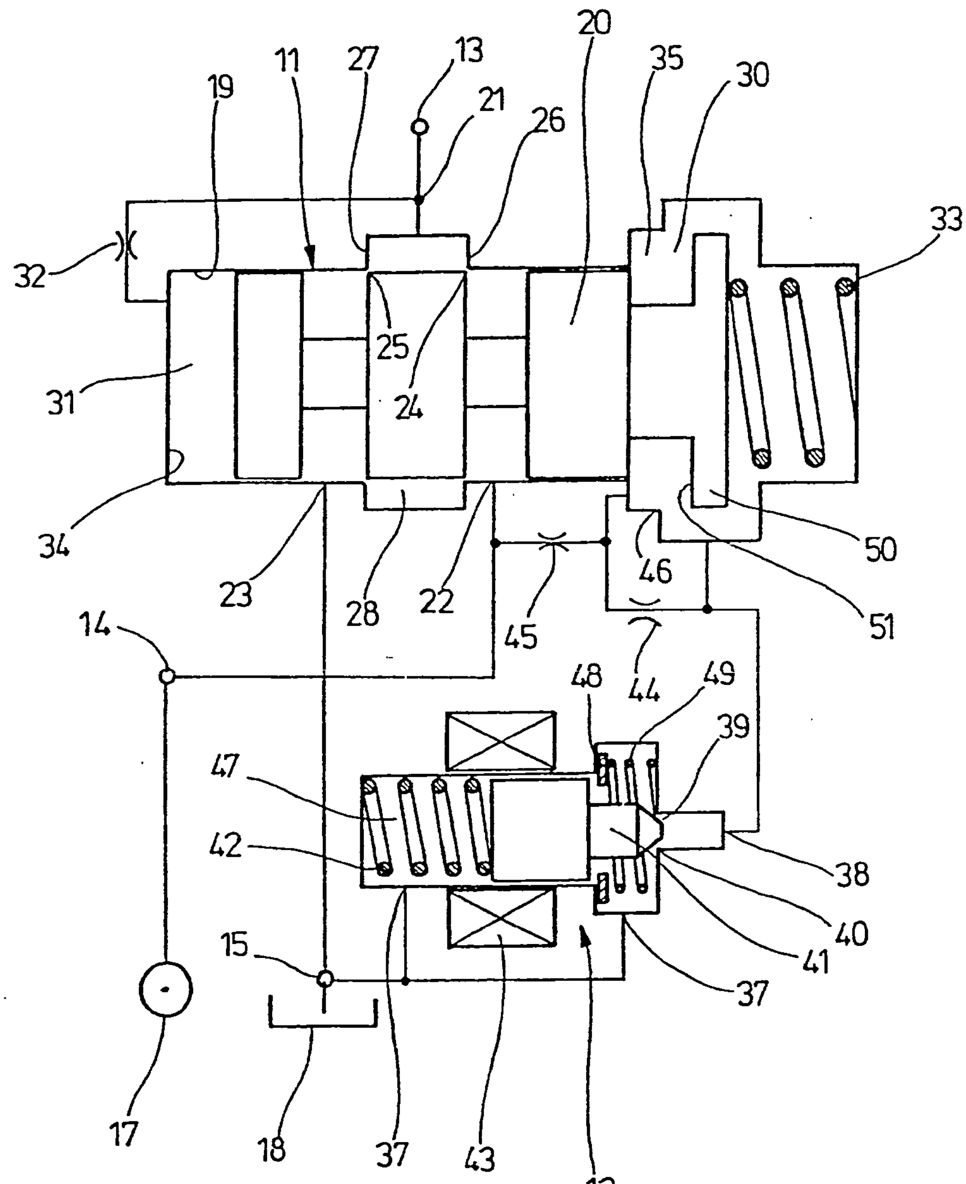
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Fig. 5

DESCRIPTION

PROPORTIONAL PRESSURE-REGULATING VALVE

The invention relates to proportional pressure-regulating valves for actuators, such as actuators for level-control devices in vehicles.

With a known proportional pressure-regulating valve for a hydraulic servomotor in lifting gear in agricultural equipment (DE 32 06 842 Al), the valve spool of the main valve is controlled by a proportional solenoid which is arranged in an electrical servo-loop position control. At the same time, the position of the valve spool is detected by an electro-magnetic travel sensor and is compared in the servo-loop with the desired value. The control of the proportional solenoid is determined by the difference signal.

If the proportional solenoid is de-energized, the valve spool adopts an end resting position in which the service port to the servo motor is closed off. It is thus possible with the end position to realise the so-called fail-safe functions. In normal operation, the proportional solenoid is energized in such a way that the valve spool adopts its mid-position or neutral position between the two operating positions, in which the service port is also closed off. By enlarging or reducing the energizing current, the

valve spool can be moved to one or the other operating position to "raise" or "lower" the equipment. By detecting the travel of the valve spool and with the servo-loop position control, the valve spool is prevented in normal operation from also being able to enter the end resting position instead of its mid-position.

A proportional pressure-regulating valve, in accordance with the invention, for an actuator comprises a main valve which has at least three controlled valve ports of which a service port can be connected to the actuator, a pressure supply port to a pressure medium source and a relief port to a pressure medium drain, and a valve spool which is displaceable by fluid pressure against a return spring and which controls the valve ports in four operating positions, the valve spool being displaceable from a neutral mid-position blocking the service port, in opposite directions respectively towards first and second operating positions, at which a connection is established from the service port to the pressure supply port or to the relief port and the valve spool being biased by the return spring to move the valve spool, upon failure of the axial force, into an end resting position in which the service port is blocked off, and a pilot valve for controlling the fluid

pressure to shift the valve spool, a damping piston being fixedly connected to the valve spool and delimiting a damping chamber which is connected to the pilot valve, the arrangement being such that, during the opening phase of the pilot valve, a minimum pressure which is applied to the damping piston against the force of the return spring is so controlled as to prevent the valve spool from being returned to its end resting position.

This has the advantage that, without involving the proportional pressure-regulating valve, it is guaranteed that the valve spool of the main valve can at no time during the pressure regulating process enter the end position and there is therefore no non-linearity in the normal operation. Having the servo loop position control, there is no requirement to detect the travel of the valve spool, so that the proportional pressure-regulating valve in accordance with the invention is more economical and particularly suitable for economic applications.

In accordance with an advantageous embodiment of the invention, the pilot valve has a proportional solenoid which drives a valve element against the force of a valve closure spring in order to open the valve. In this way it is possible to have, on the one hand, only one proportional solenoid and, on the other

hand, only a low hydraulic current to control the main valve.

Adjustments to the minimum pressure maintained in the damping chamber during the control process by the pilot valve to prevent the valve spool returning to the fail-safe end position can be carried out by alternative structural measures in conjunction with modulating the levels in the control chamber for the valve spool. In one embodiment of the invention, the pilot valve lies in the pressurised region of the main valve, that is to say, it receives pressure from the pressure medium source, whereas with another embodiment of the invention, the pilot valve is arranged in the unpressured valve region of the main valve, that is to say, it discharges pressure medium to drain.

In accordance with a preferred embodiment of the invention, the control characteristic curve of the pilot valve is such that, in the displaced position allocated to the minimum energizing current, such a non-linearity occurs that, in order to continue the displacement, the energizing current must be increased by a preset amount. This enables proportional solenoids with relatively high tolerance ranges in their magnetic characteristic curve to be used for the pressure regulating valve.

The invention is described further, by way of example, with reference to the accompanying drawings, in which:-

Fig.1 is a basic circuit diagram of a proportional pressure-regulating valve in accordance with the invention;

Fig.2 is a graph of the control characteristic curve of the pilot valve of the proportional pressure-regulating valve of Fig.1;

Fig.3 and Fig.4 are illustrations similar to Fig.1, but showing other positions of the valve spool in the main valve of the pressure regulating valve of Fig.1; and

Fig.5 is a basic circuit diagram of a proportional pressure regulating valve in accordance with a further embodiment of the invention.

The proportional pressure regulating valve illustrated in the basic circuit diagram comprises a main valve 11 and a pilot valve 12 which are preferably fitted in a common valve block 10. Ports 13, 14 and 15 of the pressure regulating valve block act as connecting points for a hydraulic working cylinder or actuator 16, a pressure medium source 17 and a pressure medium drain 18. The pressure medium drain 18 is normally formed by a hydraulic oil tank and the pressure medium source 17 by a supply pump feeding from the hydraulic oil tank.

The main valve 11 is a hydraulically controlled 3/4-proportional directional-control valve with spring return. It has three valve ports, namely a service port 21 which leads to a port 13 of the pressure regulating valve block 10, a pressure supply port 22 which leads to a port 14 and a relief port 23 which is connected to a port 15. Such connections are achieved here by corresponding bores in the valve block 10. The three valve ports 21 to 23 are controlled by a valve spool 20 in four valve spool positions or operating positions of the valve spool 20. In addition to this, the valve spool 20, axially displaceable in a bore 19 of the valve block 10, has two control edges 24,25 which interact with two control edges 26,27, on an annular groove 28 which is recessed in the bore 19. The service port 21 issues from the annular groove 28, whereas the pressure supply port 22 and the relief port 23 issue from the bore 19 to the left and to the right next to the annular groove 28. Moreover, a control piston 29 is formed on the valve spool 20, the front end of the control piston 29 de-limiting a control chamber 30. The front side, facing away from the control piston 29, of the valve spool 20 limits a damping chamber 31 which is connected by means of a restrictive bore 32 to the annular groove 28. A return spring 33 is

accommodated in the damping space 31, the return spring 33 being supported by one end against the valve block 10 and by its other side against the valve spool 20. The return spring 33 is designed in such a way that, if the control chamber 30 is unpressurised it moves the valve spool 20 into the end or resting position, which is defined by an abutment shoulder 34 in the valve block 10. In this end position illustrated in Fig.4, the so-called fail-safe position, the valve spool 20 blocks all three valve ports 21 to 23. A damping chamber 35 is formed as an axial recess in the valve block 10 at the base of the control chamber 30, which lies opposite the front face of the control piston 29, the damping chamber 35 being open to the control chamber 30. On the front face of the control piston 29 there is a small damping piston 36 with a reduced diameter compared with that of the control piston 29. The outer diameter of the damping piston 36 is at the same time slightly smaller than the diameter of the damping chamber 35, so that the damping piston 36 in the fail-safe position of the valve spool 20 is enabled to penetrate the damping chamber 35.

The pilot valve 12 has a valve aperture 39 arranged between a valve port 37 and a valve outlet 38, a valve seat 40 being formed about the valve aperture 39. A valve element 41 designed as a valve

cone interacts with the valve seat 40, the valve element being pressed onto the valve seat 40 by a valve closure spring 42 and being driven in the opening direction by a proportional solenoid 43. The control characteristic line of the pilot valve 12 (I against f(s)) is illustrated in Fig.2, where I represents the energizing current of the proportional solenoid 43 and s represents the travel of the valve element 41. The valve inlet port 37 leads from the pressure supply port 22 of the main valve 11 and therefore from the valve port 14 for the pressure medium source 17. A further connection leads from the valve inlet 37 port to a spring chamber 47 accommodating the valve closure spring 42, the spring chamber 47 being sealed by the valve element 41. The valve outlet 38 is on the one hand connected directly to the damping chamber 35 of the main valve 11 and on the other hand by means of a throttle 44 to the control chamber 30 of the main valve 11. A further throttle 45 is fitted between the outlet of this throttle 44 and the relief port 23 or rather the port 15 of the pressure regulating valve housing 10. The cross-section of this further throttle 45 is substantially greater than that of the throttle cross-section of the throttle 44. The connections and throttles 44,45 are on the other hand produced by

corresponding bores or throttle bores in the valve block 10.

As is shown by the characteristic curve of the pilot valve 12 illustrated in Fig.2, the valve element 41 of the pilot valve 12 in normal operation performs a lifting movement between s_1 and s_2 for which an energizing current between I_1 and I_2 is fed to the proportional solenoid 43. The valve element 41 is at the same time designed in such a way that, in its displaced position s_1, the throttle cross-section uncovered by it in the valve aperture 39 is somewhat greater than the throttle cross section of throttle 44. In this way, the pressure in the damping chamber 35 is controlled so that the damping piston 36 cannot travel beyond the control edge 46 formed at the point where the damping chamber 35 becomes the control chamber 30 and thus the damping piston 36 cannot penetrate into the damping chamber 35. This ensures that, during the control operation, the valve spool 20 cannot be returned by the return spring 23 into its end position "fail-safe" as is illustrated in Fig.4.

The function of the pressure regulating valve described is illustrated in Figs. 1 to 4.

When placing the pressure regulating valve in operation, the proportional solenoid 43 of the pilot valve 12 is subjected to an energizing current lying between I_1 and I_2, which is sufficient to control the

pressure in the control chamber 30 of the main valve 11 to move the valve spool 20 into its mid position illustrated in Fig.1, in which the three valve ports 21,22,23 of the main valve 11 and thus the valve ports 13,14,15 of the pressure regulating valve housing 10 are sealed. If the pressure in the actuator 16 is to be increased, then the energizing current is reduced. In this way the pressure in the control chamber 30 is reduced and the valve spool 20 moves towards the left in Fig.1 so that pressure medium can now flow from the pressure supply port 22, between the control edges 24 and 26 to the operating port 21. The energizing current of the proportional solenoid 43 is at the same time reduced to no less than I_1. In this position, as described, such a pressure is maintained in the damping chamber 35, that the damping piston 36 cannot penetrate it. The valve spool 20 takes up its displaced position illustrated in Fig.3. The passage between the pressure supply port 22 and the service port 21 is fully open. By correspondingly increasing the energizing current of the proportional solenoid 43 up to the amount I_2, the control valve spool 20 can be pushed towards the right against the return spring 33 in Fig.1 and it is now possible for the pressure medium to drain from the service port 21 between the control edges 25 and 27 to the relief port 23 of the

main valve 11. The pressure medium drained off is returned to the pressure medium drain 18 by way of the valve port 15. The pressure in the actuator 16 is reduced. If the control of the proportional solenoid 43 fails, then the valve element 41 is pressed onto the valve seat 40 by the valve closure spring 42 of the pilot valve 12 and the valve aperture 39 is closed. The pressure in the damping chamber 35 drops and the valve spool 20 with the damping piston 36 pushed back by the return spring 33 can penetrate the damping chamber 35 up to the resting point on the contact shoulder 34. The valve spool 20 has achieved its fail-safe position in which the valve ports 21,22,23 of the main valve 11 are sealed. (Fig.4).

The non-linearity (jump in the energizing current I) provided at the displacement position s_1 of the valve element 41 in the control characteristic curve of the pilot valve 12 facilitates the use, in the pilot valve 12, of proportional solenoids 43 with a relatively wide tolerance range in the magnetic characteristic curve. This non-linearity is caused by a spring 49, which operates in the direction of the valve aperture and is supported by way of an abutment ring 48 on the valve element 41, and by the dynamic effect of the spring 49 being increased as soon as the abutment ring 48 engages a shoulder provided on the valve housing 10.

A further embodiment of the proportional pressure regulating valve is illustrated in Fig.5. This embodiment differs substantially from the pressure regulating valve of Fig.1 in that the pilot valve 12 is arranged in the unpressured region of the main control valve 11. Otherwise the construction and the method of functioning of this valve are to a large extent identical to the pressure regulating valve described with reference to Fig.1, so that the same components are denoted by the same reference characters. In the main valve 11, the control piston and the damping piston are realised by an annular flange 50, with the return spring 33 being supported on the front face (facing away from the valve spool 20) of the annular flange 50. The annular surface 51, facing the valve spool 20, of the annular flange 50 forms the surface of the damping piston; pressure acts on this surface and this surface de-limits the damping chamber 35. The damping chamber 35 is in turn designed as an axial recess in the base, opposite to the annular surface 51, of the control chamber 30, with the diameter of this recess being slightly larger in size than the outer diameter of the annular flange 50. The valve inlet 37 is connected to the valve port 15 of the pressure regulating valve housing 10 and at the same time connected to the pressure medium drain

18. The valve port 38 of the pilot valve 12 leads directly from the control chamber 30 and, via the throttle 44, from the damping chamber 35. The throttle 45 is connected between the pressure supply port 22 of the main valve 11 and the inlet of the throttle 44 to the damping chamber 35. The pilot valve 12 is in turn driven with the control characteristic curve illustrated in Fig.2. With the displaced position s_1 of the valve element 41, the pressure in the damping chamber 35 is so controlled that the annular flange 50 cannot travel beyond the control edge 46 on the damping chamber 35, so that it is also guaranteed here that, during normal operation, the valve spool 20 cannot be pushed back into its end position "fail-safe" by the return spring 33.

The invention is not limited to the embodiments described. Therefore it is also possible to use compressed air as a pressure medium.

CLAIMS

1. A proportional pressure-regulating valve for an actuator, comprising a main valve which has at least three controlled valve ports of which a service port can be connected to the actuator, a pressure supply port to a pressure medium source and a relief port to a pressure medium drain, and a valve spool which is displaceable by fluid pressure against a return spring and which controls the valve ports in four operating positions, the valve spool being displaceable from a neutral mid-position blocking the service port, in opposite directions respectively towards first and second operating positions, at which a connection is established from the service port to the pressure supply port or to the relief port and the valve spool being biased by the return spring to move the valve spool, upon failure of the axial force, into an end resting position in which the service port is blocked off, and a pilot valve for controlling the fluid pressure to shift the valve spool, a damping piston being fixedly connected to the valve spool and de-limiting a damping chamber which is connected to the pilot valve, the arrangement being such that, during the opening phase of the pilot valve, a minimum pressure which is applied to the damping piston against the force of the return spring is so controlled as to prevent the valve spool from being

returned to its end resting position.

2. A valve as claimed in claim 1, in which the valve spool has a control piston which de-limits a control chamber, the damping piston is adjacent to the control piston and the damping chamber is directly adjacent to the control chamber and is open to this, and in which the valve outlet of the pilot valve is, on the one hand, connected to the damping chamber and, on the other hand, to the control chamber.

3. A valve as claimed in claim 1 or 2, in which the pilot valve has a proportional solenoid which, in order to open the valve, drives a valve element biassed in the direction of valve closure by a valve closure spring.

4. A valve as claimed in claim 3, in which the damping piston having a smaller outer diameter, coaxially protrudes from a front surface of the control piston and de-limits the control chamber, and the damping chamber, open to the control chamber, is formed by an axial recess in the housing at the bottom of the control chamber opposite the damping piston, with the diameter of the control chamber being slightly larger than the outer diameter of the damping piston, and in which the valve inlet of the pilot valve is connected to the pressure supply port of the main valve and the valve outlet of the pilot valve is

connected, on the one hand directly to the damping chamber and, on the other hand, to the control chamber via a first throttle, and a second throttle with a substantially larger throttle cross-section is arranged between the port of the first throttle at the control chamber and the relief port of the main valve and, furthermore, in which the minimal energizing current for the proportional solenoid of the pilot valve is set in such a way that the flow cross section of the opening uncovered by the valve element on the valve aperture is somewhat larger than the throttle cross-section of the first throttle.

5. A valve as claimed in claim 3, in which the damping piston and the control piston are realised by an annular flange on the valve spool, the return spring being supported on the front face, facing away from the valve spool, of the annular flange, the annular surface of the annular flange facing the valve spool forms the surface of the damping piston which is subjected to the fluid pressure, and the damping chamber open to the control chamber is formed by an axial recess in the housing at the base of the control chamber opposite the annular surface of the annular flange, whose diameter is slightly larger than the outer diameter of the annular flange, and in which the valve inlet of the pilot valve is connected to the relief port of the main valve and its valve outlet is

connected, on one hand, directly to the control chamber and, on the other hand, by way of a throttle to the damping chamber, and a second throttle having a substantially larger throttle cross-section compared with the first throttle, is arranged between the port of the first throttle on the damping chamber and the pressure supply port of the main valve, and, furthermore, in which the minimal energizing current for the proportional solenoid of the pilot valve is set in such a way that the flow cross section of the valve aperture uncovered by the valve element is somewhat larger than the throttle cross-section of the first throttle.

6. A valve as claimed in claim 4 or 5, in which the valve spool by its front end facing away from the control piston de-limits a damping chamber which is connected by way of a throttle to the service port of the main valve.

7. A valve as claimed in claim 4 or 6, in which the return spring is enclosed in the damping chamber.

8. A valve as claimed in any of claims 3 to 7, in which the control characteristic curve of the pilot valve is such that, with a displaced position (s_1) of the valve element allocated to a minimum energising current (I_1) of the proportional solenoid, such non-linearity occurs that, in order to continue the

displacement, the energized current (I) must be increased by a preset amount.

9. A proportional pressure-regulating valve, constructed and adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.
